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Cooperative Studies of the Delayed Harvesting of Sweetpotatoes

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FACTORS INVOLVED IN EXTENDING THE HARVEST PERIOD OF SWEETPOTATOES

Background and Summary

One of the most important elements in the success of an industrial or a manufacturing business is an abundant supply of cheap raw materials. Sweetpotatoes for the preparation of starch or dehydrated products for human food or for livestock feed are available at low prices for only a short time each year. The manufacturer is interested in increasing the time during which inexpensive raw stock is available

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[1] George P. Hoffmann, deceased, formerly horticulturist, conducted the 1940 trials and preceded C. E. Steinbauer and M. T. Deonier in the studies at Meridian, Miss.

[2] Acknowledgment is made of the assistance of Belton Walters, agricultural aid, and J. L. Williams, formerly agent, in making the starch determinations.

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each year in order to operate his factory over a longer season with more efficiency and with lower costs per unit of product.

Sweetpotatoes stored in conventional storage houses are too expensive for making starch or livestock feed. If sweetpotatoes for manufacturing would remain in a satisfactory condition in the soil after frost, the period of availability to the manufacturer would be extended and the grower could harvest them over a long period and would not be burdened with large quantities of a perishable commodity. It has long been known that the eating and long-time storage qualities of sweetpotatoes are impaired if harvest is delayed long after frost, for sweetpotatoes are damaged by soil temperatures between 40° and 50° F. and deteriorate rapidly at temperatures well above freezing.

Various questions about delaying the harvest of sweetpotatoes, especially for industrial uses, still require answers. How long can harvest be delayed after frost kills the vines without resultant heavy losses in quality or yield of sound roots? Can the frosted vines be used to help protect the roots remaining in place in the soil? If roots will not keep in the soil for a profitable length of time can they be kept in unheated sheds long enough to increase the season of factory operation significantly? The studies reported in this circular were conducted to ascertain how long after frost sweetpotatoes intended primarily for industrial uses can be harvested without serious loss from spoilage or reduced starch content.

Experiments were conducted for 3 years at Meridian, Miss., and Baton Rouge, La., and for 2 years at Gilmer, Tex. Under those conditions the yields of apparently sound roots usually showed only slight decreases with delays of harvest as long as 5 or 6 weeks after the first killing frost. Delays as long as 8 or 9 weeks, however, resulted in serious decreases in yields of sound roots. Although short delays in harvest usually caused no immediate loss in yield, roots that were harvested more than 2 weeks after frost spoiled more quickly and had less starch and less solids than those harvested at frost or before. These harmful effects became more serious as the time of harvest was further delayed.

Delays of 5 or 6 weeks in harvesting Triumph roots caused reductions in starch content (fresh-weight basis) of approximately 3 to 6 percentage points, while delays of 8 to 11 weeks caused reductions up to 10 percentage points as compared with harvests made before or at time of frost. These reductions amounted to as high as one-fourth and two-fifths, respectively, of the amount of starch present in similar roots dug before frost. Despite reduced starch percentages resulting from the first frost that killed at least half of the leaves, maximum yields of starch per acre were sometimes observed 2 weeks later because of continued root growth. Significant reductions in yields of starch per acre usually resulted with longer harvest delays. Maximum content of starch in raw stock was obtained at or before the time of the first killing frost.

Sweetpotato vines offered no apparent protection to the roots, either when left undisturbed or when raked over the row with or without additional soil coverings. In fact, in some tests, particularly with long delays in digging, there was more rotting if the vines alone were raked over the rows or if soil was plowed over the vine-covered rows than if the rows were undisturbed. This was due, presumably, to disturbance of roots in the ground. Cutting and leaving vines at the hill immediately after frost was of no benefit in preventing rotting or in reducing loss of eating quality of roots when harvests were delayed. The starch content of sound roots left in the ground was not significantly altered by the vine treatments used, even with delays in harvest as long as 8 weeks after frost.

There were small reductions in starch content, 1.6 to 4.4 percent of the amount of starch present in freshly harvested stock, when roots were held in common (unheated) shed storage for 1 week immediately after harvest.

Common shed storage of Triumph roots for as long as 2 months usually proved practical only on stock harvested no later than 2 weeks after killing frosts. Only in those cases when the weather remained very mild and storage temperatures were relatively high were roots of late-harvested lots held successfully for 2 months in this type of storage. Edible quality of Porto Rico roots was impaired by low temperatures resulting from both delayed digging and unheated storage.

Practical Recommendations

1. For both market and industrial purposes, wherever possible, harvest sweetpotatoes before or immediately after the first killing frost, because conditions for digging are usually better at those times, air temperatures are more favorable for partial curing, especially when unheated storage is to be used, edible quality is not impaired, and chemical composition is altered the least by soil and air temperatures.
2. For obtaining maximum content of starch in industrial raw stock, harvest roots before or immediately after frost. Progressive decreases in starch content can be expected to occur with successively longer delays in harvesting.
3. Although there may be no decrease in yields of apparently sound roots for 5 or 6 weeks after frost, harvest sweetpotatoes for industrial use within 2 weeks after the first killing frost if the highest yields of starch per acre are to be obtained.
4. Leave vines undisturbed after frost. There is no apparent value in cutting sweetpotato vines at the hill immediately after frost. Neither is any appreciable protection afforded the roots by raking vines over the row, with or without additional soil covering, at the time of the first killing frost.
5. Sound sweetpotatoes for industrial uses may be held in common shed storage as long as 1 week after harvest without serious reduction in starch content.
6. Common shed storage of sweetpotato roots of industrial type for periods up to 2 months after harvest is practical only for roots harvested within 2 weeks after the first killing frost, except where outside temperatures during the storage period remain very mild and where storage temperatures remain at or well above 50° F.
7. Store table varieties of sweetpotatoes in unheated sheds only when exceptionally favorable temperatures prevail and then for only brief periods to meet some emergency. The eating quality of sweetpotatoes deteriorates rapidly when they are exposed to temperatures below 50° F., either in the soil or in storage.

EXPERIMENTAL METHODS AND MATERIALS

The experiments reported in this circular were conducted at Meridian, Miss., and Baton Rouge, La., in 1940, 1941, and 1942 and at Gilmer, Tex., in 1941 and 1942. They were based in part on the preliminary work of Hoffmann and Lutz (*3*).[3]

Two varieties of sweetpotatoes were used: Triumph, representing the starch type, and the Unit I strain of Porto Rico, representing the culinary or high-carotene feed type. Kimbrough (*4*) reported on the studies conducted with the Porto Rico variety at Baton Rouge. Only portions of those data are republished here, but the main conclusions are included.

Each field plot consisted of a single 40-foot row. Rows were 4 feet apart at Meridian and Baton Rouge and 3½ feet apart at Gilmer. Each treatment was replicated four times in each test. Locally prevailing methods of field culture and fertilizing were used at each location so that the results would be representative of the production area.

The split-plot experimental design included the following primary and secondary treatments:

1. Primary (vine-cutting-and-covering treatments at the time of the first killing frost):[4]
   - *a.* Vines undisturbed.
   - *b.* Vines cut at hill, but not moved.
   - *c.* Vines cut at hill and in furrow; then raked over row.
   - *d.* Same as *c*, but with soil plowed over the vine-covered row.
2. Secondary (intended times of harvest):
   - *a.* Before first killing frost.
   - *b.* Immediately after first killing frost.
   - *c.* 2 weeks after frost.
   - *d.* 5 weeks after frost.
   - *e.* 8 weeks after frost.

For various reasons some of the plots in some tests could not be dug as intended. Unexpectedly late frosts altered the plans in some cases. The harvest dates or periods of time before and after frost actually used in the several tests are given in table 1. Although it was planned to make the before-frost harvests at approximately 2 weeks before the first-killing-frost dates, actually the number of days fluctuated widely among tests, since there was no way of knowing in advance just when the first killing frosts would occur. In order to facilitate discussion the intended time of harvest is usually indicated in this circular. Deviations of actual harvests from the intended times are designated in the data tabulations.

Soil temperatures were recorded at the approximate average depth of the storage roots in one or more of the field replicates of the several primary treatments during the harvest period in all three seasons at Meridian, in 1941 and 1942 at Gilmer, and in 1940 at Baton Rouge. Continuous-recording soil thermographs were used when available; otherwise ordinary hotbed-type soil thermometers were used.

At each harvest the roots were plowed out and the weights of sound and unsound roots were determined. Since it was not possible to

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[3] Italic numbers in parentheses refer to Literature Cited, p. 22.

[4] For purposes of these studies a killing frost was considered as a frost causing killing of at least half of the leaves.

TABLE 1.—*Periods between first killing frosts and actual harvest dates in sweetpotato tests in 3 years at 3 locations*

Location, variety, and year	Frost date	Period harvested before frost	Period between frost and indicated harvest after frost		
			First	Second	Third
Meridian:					
Triumph and Porto Rico:		*Days*	*Days*	*Days*	*Days*
1940	Oct. 17	1	42	62	77
1941	Nov. 10	18	14	35	56
1942	Nov. 12	21	13	35	55
Baton Rouge:					
Triumph:					
1940	Nov. 15	24	14	35	--------
1941	Nov. 25	26	14	--------	--------
1942	Dec. 17	50	13	34	--------
Porto Rico:					
1940	Nov. 15	24	14	35	--------
1941	Nov. 25	27	7	14	28
1942	Dec. 17	50	6	13	20
Gilmer:					
Porto Rico:					
1941	Nov. 12	27	7	63	--------
1942	Oct. 28	5	7	28	55

determine accurately the weights of unsound (decayed) roots at harvest, only data on total yields of sound roots are considered in this circular. At Meridian and Baton Rouge representative root samples of the Triumph variety and at Baton Rouge those of the Porto Rico variety were drawn for starch analysis. Starch analyses for these tests were made at the United States Horticultural Field Station Laboratory, Meridian, Miss., by the Balch method (*1*) developed for sweetpotatoes.

At each harvest in each season 1 crate holding about 1 bushel of reasonably clean representative roots from each plot was weighed and placed in common shed storage. At the end of 1 week the stored crates were again weighed, representative 10-root samples were drawn for starch analysis from each of the crates representing the field replicates sampled at harvest, then the crates were reweighed, and the common storage was continued on all lots for a total of 2 months. At the end of this period the weights of sound and unsound roots were ascertained for each crate separately. The variance method (*8*) was used in statistical analysis of data.

SOIL TEMPERATURES OCCURRING BEFORE DELAYED HARVESTS

Sweetpotatoes are known to be very sensitive to chilling injury (*5, 6*). Temperatures considerably above the freezing point may cause damage if the roots are exposed to them for even a few days.

Although the lowest temperatures recorded were reached within the first 2 to 6 weeks after frost in two tests, data of table 2 show that

TABLE 2.—*Soil temperatures*[1] *during harvest-delay periods after first killing frosts at Meridian, Baton Rouge, and Gilmer*

Year	Harvest delay period (weeks)	Temperature for location and period indicated									
		Meridian						Baton Rouge		Gilmer	
		Between frost and harvest			7 days preceding harvest			Between frost and harvest	7 days preceding harvest	Between frost and harvest	7 days preceding harvest
		Maximum	Minimum	Mean	Maximum	Minimum	Mean	Minimum	Minimum	Minimum	Minimum
		°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
1940	2							38	46		
	5 or 6	76	34	56.0	69	42	56.5	38	44		
	9	76	34	59.0	64	42	53.0				
	11	76	34	55.0	62	42	52.0				
1941	1									46	46
	2	68	42.5	55.0	68	46	57.0				
	5	68	39	53.5	54	39	46.5				
	8 or 9	68	36	52.0	62	36	49.0			32	32
1942	1									58	58
	2		42			45					
	4 or 5		34			34				48	48
	8		32			32				41	42

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[1] At the average depth of storage roots.

successively lower minimum temperatures continued to occur with increasingly longer harvest delays in most of the tests. Minimum soil temperatures, in four of the six tests for which soil temperatures were recorded, dropped 6.5° to 17° F. lower during the succeeding 6 or 7 weeks than during the first 1 or 2 weeks after frosts. Perhaps more important than the lowest minimum temperatures reached during the periods preceding each harvest are the durations of temperatures below about 40°. During fall months there is a progressive lowering of soil temperatures, so that the roots of each successive harvest are exposed for successively longer periods to lower mean temperatures and greater opportunity is thus presented for cold injury.

INFLUENCE OF VARIOUS FACTORS ON YIELDS OF SOUND POTATOES

Times of Harvest

The data shown in table 3 for mean total yields[5] of sound sweetpotatoes from the plots with undisturbed vines emphasize the importance of time of harvest in relation to yields. In all 3 years at Meridian yields of sound Porto Rico roots were significantly lower when digging was delayed 8 or 9 weeks after frost than when the delay was either 6 weeks or less. The yield reduction for the Triumph variety with a harvest delay up to 8 weeks after frost was significant compared with shorter delays only in 1942.

With both varieties in each of the 3 years the mean yields of sound roots at the 8- or 9-week delayed harvest tended to be lower than at earlier harvests, although the yield differences were not always statistically significant. Only for Porto Rico in 1940 and Triumph in 1942 were the yields significantly lower 5 or 6 weeks after frost than at either the time of frost or 2 weeks thereafter. Statistical analysis of the 1940 and of the 1942 Meridian yields combined for the two varieties (data not presented) indicated significant variations due to times of harvest in both years when referred to error. The variances due to times of harvest in both years, however, lacked significance when compared with the variances for times of harvest × varieties. The response to delayed digging was therefore more or less dependent on the variety involved.

In order to evaluate possible over-all influences of times of harvest at Meridian, yield data were combined and analyzed for five harvest periods in 1941 and 1942, and for four harvest periods in the three test years. Mean yields are shown in table 4, and variance data for times of harvest are summarized in table 5. These data show that when harvests were delayed 8 or 9 weeks mean yields were significantly lower than when delays were either 5 (or 6) weeks or shorter in all cases except for Triumph in the 1940–42 combined data. In no case were the mean yields for harvests delayed 5 or 6 weeks significantly lower than those either delayed 2 weeks or made at frost. The statistical data of table 5 indicate that variances due to times of harvest, to the interaction times of harvest × years, and to the interaction

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[5] All yields reported in this circular were calculated on the basis of 55 pounds per bushel.

TABLE 3.—*Mean yields per acre of sound sweetpotato roots harvested at different times from undisturbed-vine plots in 3 years at 3 locations*

Location and year	Variety	Sound roots at intended time of harvest indicated (and least significant difference)					
		Before frost	At frost	2 weeks after frost	5 weeks after frost	8 weeks after frost	Least significant difference [1]
		Bushels	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
Meridian:							
1940	Triumph	121	130	-------	[2] 123	[3] 118	29
	Porto Rico	130	157	-------	[2] 106	[3] 103	29
1941	Triumph	362	342	434	446	417	(4)
	Porto Rico	174	182	198	227	188	34
1942	Triumph	432	417	472	400	381	66
	Porto Rico	317	400	394	415	205	66
Baton Rouge:							
1940	Triumph	351	467	355	301	-------	(4)
	Porto Rico	314	330	299	316	-------	(4)
1941	Triumph	372	425	464	-------	-------	(4)
	Porto Rico	415	454	472	[5] 513	-------	(4)
1942	Triumph	352	341	393	305	-------	(4)
	Porto Rico	265	288	346	[6] 341	-------	57
Glimer: [7]							
1941	Porto Rico	216	332	[8] 287	-------	[3] 58	147
1942	Porto Rico	211	208	[8] 147	[5] 184	204	(4)

[1] At 5-percent level.
[2] 6 weeks after frost.
[3] 9 weeks after frost.
[4] Differences lack significance at 5-percent level.
[5] 4 weeks after frost.
[6] 3 weeks after frost.
[7] Triumph not tested at Gilmer.
[8] 1 week after frost.

times of harvest × varieties were all highly significant with reference to error. The times-of-harvest variances lacked significance, however, when referred to either the interaction times of harvest × years or the interaction times of harvest × varieties. In other words, the effects of delays in times of harvest were influenced significantly by both the variety and the season.

At Baton Rouge intended harvest delays of either 2 or 5 weeks after frost resulted in no significant decreases in yields of sound potatoes as compared with harvests made at the first-killing-frost dates in any of the 3 years of these tests. Nevertheless, as shown in table 3, in four of five tests the average yields for the intended 5-week-after-frost harvests were smaller than those for harvests made either at frost or after only a 2-week delay. No data were gathered on yields for harvests made 8 weeks after frost at Baton Rouge. In 1940 Porto Rico potatoes were so badly rotted in a digging made 8 weeks after frost at this location that no records on yields were kept (*4*). It may be presumed, therefore, that material reductions in yields of

TABLE 4.—*Mean yields per acre of sound sweetpotato roots when Meridian data from undisturbed-vine plots are combined by years and varieties*

Years for which data are combined	Variety	Sound roots at time of harvest indicated (and least significant difference)					
		Before frost	At frost	2 weeks after frost	5 or 6 weeks after frost	8 or 9 weeks after frost	Least significant difference[1]
		Bushels	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
1941 and 1942	Triumph	397	380	453	423	399	47
	Porto Rico	246	291	296	321	197	47
	Mean	322	335	375	372	298	33
1940, 1941, and 1942	Triumph	305	296	-------	323	305	40
	Porto Rico	207	246	-------	249	166	40
	Mean	256	271	-------	286	235	23

[1] At 5-percent level.

sound roots resulting from delays in harvest as long as 8 weeks after frost might well have occurred at Baton Rouge also in 1941 and 1942.

At Gilmer a significant reduction in average yield of sound roots occurred in 1941 when the harvest was delayed 9 weeks after frost, but in 1942 no significant decrease was observed when the delay was 8 weeks.

From a yield standpoint alone it appears that, under climatic conditions like those in the present experiments, harvest delays up to 5 or 6 weeks after the first killing frost may not cause serious losses in apparently sound roots, but that delays as long as 8 or 9 weeks may result in considerable losses of sound material. It should be remembered, however, that delays in digging may cause more or less alteration in root quality, keeping properties, and composition even though yields may not be materially changed. Poorer eating quality and higher moisture content (see table 11, p. 17) were found in the later dug Porto Rico roots at Baton Rouge (*4*). It is important to harvest sweetpotatoes before a killing frost in the Baton Rouge district despite the fact that the tests indicated that there is sometimes no damage to the roots apparent at the time of delayed digging. Soil conditions are usually better for harvesting before frost, and air temperatures at that time are more favorable for partial curing of the roots in the unheated storage houses commonly used in that district than they are likely to be if the digging is delayed. More careful handling and prompt transfer to the curing house are imperative when the roots are dug during the cool or cold weather likely to be encountered after killing frosts.

TABLE 5.—*Analyses of variance for combined variety data summarized in table 4*

Years for which data were combined	Source of variation	Degrees of freedom	Variance
1941 and 1942	Times of harvest	4	17, 416**
	Times of harvest × years	4	14, 521**
	Times of harvest × varieties	4	8, 468**
	Times of harvest × varieties × years	4	5, 193
	Error	48	2, 194
	Total	64	4, 495
1940, 1941, and 1942	Times of harvest	3	11, 211**
	Times of harvest × years	6	11, 815**
	Times of harvest × varieties	3	8, 856**
	Times of harvest × varieties × years	6	4, 736*
	Error	54	1, 595
	Total	72	3, 412

*Significant at 5-percent level when referred to error.
**Significant at 1-percent level when referred to error.

VINE-CUTTING-AND-COVERING TREATMENTS

Rather wide and inconsistent fluctuations in mean yields occurred among the 4 vine treatments in the 3 harvest-delay periods in the several tests (table 6). Analyses of the data averaged for these 3 periods indicated significant differences due to vine treatments in only 1 of 13 tests, namely with the variety Triumph at Meridian in 1942. In this case raking cut vines over the row, either with or without a soil covering, resulted in significantly lower yields of sound roots than were obtained when vines were left undisturbed.

In an attempt to ascertain more clearly the influence of the vine treatments, homogeneous data of the two varieties were combined for various tests and harvest-delay periods. These data are summarized in table 7, and analyses of variance of the data for the vine treatments are presented in table 8. Differences in sound-root yields among vine treatments were not significant for harvests made at either the intended 2-week or 5-week delays after frost. At the intended 8-week delay, yield differences among vine-treatment means were significant. Table 8 shows that these yield variations were significant with respect to both error and treatment × test variances. When results were analyzed for the data combinations 4, 5, and 6 shown in table 7, significant variances due to vine treatments were found in each case, but these treatment variances lacked significance in all three cases when referred to the respective treatment × test interaction variances. Variations in the season, soil, climatic, and other factors constituting the several tests were therefore important in determining differences in yields of sound roots among vine treatments.

Despite lack of significance of differences among vine-treatment means in some data combinations in table 7, mean yields from vine treatment *d* in which vines were cut, raked over the row, and covered

TABLE 6.—*Mean yield per acre of sound Triumph and Porto Rico sweetpotato roots obtained with 4 vine treatments when harvests were delayed up to 8 (or 9) weeks after frost in 3 years at 3 locations*

Variety, location, and vine treatment	Sound roots for year and intended harvest-delay period indicated											
	1940				1941				1942			
	2 weeks	5 weeks	8 weeks	Mean	2 weeks	5 weeks	8 weeks	Mean	2 weeks	5 weeks	8 weeks	Mean
Triumph:												
Meridian:	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
a. Vines undisturbed	------	[1] 123	[2] 118	120. 5	434	446	417	432. 3	472	400	381	417. 7
b. Vines cut at hill, not moved	------	[1] 126	[2] 134	130. 0	414	401	404	406. 3	361	436	343	380. 0
c. Vines cut at hill and in furrow, raked over row	------	[1] 120	[2] 99	109. 5	476	488	426	463. 3	365	363	276	334. 7
d. Same as *c*, but with soil plowed over vine-covered row	------	[1] 126	[2] 107	116. 5	447	434	365	415. 3	289	286	229	268. 0
Least significant difference between treatment means	------	------	------	(3)	------	------	------	(3)	------	------	------	69. 5
Baton Rouge:												
a. Vines undisturbed	355	301	------	328. 0	464	------	------	------	393	305	------	349. 0
b. Vines cut at hill, not moved	381	327	------	354. 0	459	------	------	------	348	338	------	343. 0
c. Vines cut at hill and in furrow, raked over row	352	344	------	348. 0	442	------	------	------	314	358	------	336. 0
d. Same as *c*, but with soil plowed over vine-covered row	360	320	------	340. 0	419	------	------	------	388	297	------	342. 5
Porto Rico:												
Meridian:												
a. Vines undisturbed	------	[1] 106	[2] 103	104. 5	198	227	188	204. 3	394	415	205	338. 0
b. Vines cut at hill, not moved	------	[1] 87	[2] 72	79. 5	230	213	248	230. 3	396	397	199	330. 7

See footnotes at end of table.

TABLE 6.—*Mean yield per acre of sound Triumph and Porto Rico sweetpotato roots obtained with 4 vine treatments when harvests were delayed up to 8 (or 9) weeks after frost in 3 years at 3 locations*—Continued

Variety, location, and vine treatment	Sound roots for year and intended harvest-delay period indicated											
	1940				1941				1942			
	2 weeks	5 weeks	8 weeks	Mean	2 weeks	5 weeks	8 weeks	Mean	2 weeks	5 weeks	8 weeks	Mean
Porto Rico—Continued	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
c. Vines cut at hill and in furrow, raked over row		[1] 103	[2] 115	109.0	241	196	140	192.3	338	356	128	274.0
d. Same as *c*, but with soil plowed over vine-covered row		[1] 118	[2] 76	97.0	265	264	197	242.0	340	306	153	266.3
Baton Rouge:												
a. Vines undisturbed	299	316		307.5	472	[4] 513		492.5	346	[5] 341		343.5
b. Vines cut at hill, not moved	357	279		318.0	444	[4] 514		479.0	345	[5] 326		335.5
c. Vines cut at hill and in furrow, raked over row	392	309		350.5	480	[4] 555		517.5	356	[5] 328		342.0
d. Same as *c*, but with soil plowed over vine-covered row	316	323		319.5	444	[4] 428		436.0	307	[5] 291		299.0
Gilmer:												
a. Vines undisturbed					[6] 287		[2] 58	172.5	[6] 147	[4] 184	204	178.3
b. Vines cut at hill, not moved					[6] 344		[2] 53	198.5	[6] 178	[4] 180	203	187.0
c. Vines cut at hill and in furrow, raked over row					[6] 273		[2] 77	175.0	[6] 179	[4] 174	207	186.7
d. Same as *c*, but with soil plowed over vine-covered row					[6] 250		[2] 66	158.0	[6] 161	[4] 167	162	163.3

[1] 6 weeks after frost.

[2] 9 weeks after frost.

[3] Differences not significant at 5-percent level.

[4] 4 weeks after frost.

[5] 3 weeks after frost.

[6] 1 week after frost.

TABLE 7.—*Mean yield per acre of sound sweetpotato roots for 4 vine treatments when data for harvest delays, varieties, locations, and years are combined in various ways*

Combination	Kind of data combined				Mean yield for vine treatment indicated				Least significant difference between treatment means [1]
	Intended harvest-delay period (weeks)	Variety	Location	Years	*a.* Vines undisturbed	*b.* Vines cut at hill, but not moved	*c.* Vines cut at hill and in furrow, then raked over row	*d.* Same as *c*, but with soil plowed over vine-covered row	
					Bushels	*Bushels*	*Bushels*	*Bushels*	*Bushels*
1	2	Triumph and Porto Rico.	Meridian	1941, 1942	383	378	377	361	[2]
			Baton Rouge	1940, 1941, 1942.					
2	5 [3]	do	Meridian	1940, 1941, 1942.	306	302	308	280	[2]
		Triumph	Baton Rouge	1940, 1942					
		Porto Rico	do	1940, 1941, 1942.					
		do	Gilmer	1942					
3	8 [4]	Triumph and Porto Rico.	Meridian	1940, 1941, 1942.	209	207	183	170	31
		Porto Rico	Gilmer	1941, 1942					
4	2 and 5 [5]	Triumph and Porto Rico.	Meridian	1941, 1942	368	362	367	339	10
		Porto Rico	Baton Rouge	1940, 1941, 1942.					
		Triumph	do	1940, 1942					
5	5 [6] and 8 [4]	Triumph and Porto Rico.	Meridian	1940, 1941, 1942.	251	246	228	214	32
		Porto Rico	Gilmer	1942					
6	2, 5,[5] and 8	Triumph and Porto Rico.	Meridian	1941, 1942	368	361	350	322	40
		Porto Rico	Baton Rouge	1941, 1942					

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[1] At 5-percent level.
[2] Differences lack significance at 5-percent level.
[3] 3, 4, and 6 weeks included.
[4] 9 weeks included.
[5] 3 and 4 weeks included.
[6] 4 and 6 weeks included.

TABLE 8.—*Analyses of variance for yield-data combinations summarized in table 7*

Source of variation	Combination 1		Combination 2		Combination 3	
	Degrees of freedom	Variance	Degrees of freedom	Variance	Degrees of freedom	Variance
Treatments	3	144. 7	3	325. 6	3	561. 4*
Treatments × tests	12	314. 6**	33	242. 8*	21	147. 3
Treatments × varieties	3	230. 6				
Treatments × tests × varieties	12	150. 2				
Error	90	123. 6	108	152. 4	72	157. 4
Total	120	148. 6	144	176. 7	96	167. 9

Source of variation	Combination 4		Combination 5		Combination 6	
	Degrees of freedom	Variance	Degrees of freedom	Variance	Degrees of freedom	Variance
Treatments	3	54. 2*	3	661. 7**	3	1, 187. 2**
Treatments × tests	24	30. 6	18	308. 5*	15	530. 5**
Treatments × varieties						
Treatments × tests × varieties						
Error	81	19. 3	63	143. 7	54	199. 2
Total	108	22. 8	84	197. 5	72	554. 9

*Significant at 5-percent level when referred to variance for error.
**Significant at 1-percent level when referred to variance for error.

with soil were lower than any of the other three treatments in all of the six data combinations. In four of the six cases yields from treatment *c* in which cut vines were raked over the row were lower than those from the undisturbed-vine treatment and from the cut-unmoved vine treatment. Apparently any treatment that disturbed the roots tended to increase the proportions of unsound sweetpotatoes. Raking vines over the row seemed to give no protection to the roots, and the operation appears to have caused some disturbing of roots, presumably those lying nearest the soil surface. The plowing of soil over the vine-covered row caused the greatest reduction in yield of sound potatoes. It is impossible to plow the soil over the vine-covered row without disturbing the roots more or less and exposing some to cold injury. Kimbrough and Bell (*5*) reported this to be true at Baton Rouge. The longer the harvests were delayed after the vine treatments were applied the greater tendency there was for reduction in yield of sound roots resulting from adverse effects of those treatments. It is apparent, therefore, that in general, if harvesting is delayed after frost, no beneficial results will be obtained from such "protective" treatments as were applied in these tests and under some conditions definite injury to the keeping quality of the roots may result.

INFLUENCE OF VARIOUS FACTORS ON STARCH CONTENT OF ROOTS

Times of Harvest

In all tests, with the exception of that with Triumph at Baton Rouge in 1941, the highest mean starch content at harvest was found at the before-frost harvest dates and the mean starch percentage decreased progressively and in most cases significantly thereafter with successive harvest delays within the periods studied (tables 9 and 10). The reductions in actual starch contents were approximately 3 to 6 percentage points (fresh-weight basis) for harvest delays up to 5 or 6 weeks and approached 10 percentage points in some cases with delays of 8 to 11 weeks. These reductions during 5- or 6-week delays in harvesting may amount to as much as one-fourth of the starch present per unit of fresh weight before frost. The corresponding decreases with delays of 8 to 11 weeks may be as high as two-fifths of the starch content before frost.

Progressive increases in the moisture content of roots accompanying successively longer digging delays account for part of these reductions in starch content (table 11). Generally the moisture content of roots increased with each further harvest delay after frost, and in about half of the tests increases over the moisture content before frost were evident at time of frost. Changes in moisture content, however, do not account for all of the reduction in starch content in the freshly harvested roots. Hasselbring and Hawkins (*2*) and Kimbrough (*4*) showed significant decreases in the starch content accompanied by increases in sugar in sweetpotato roots left in the ground after the vines were killed by frost.

Inasmuch as in the majority of these tests yield of sound roots per acre increased up to the time of frost (tables 3 and 4) and in several cases for two or more weeks after frost, there may be over-all increases in starch produced per acre with short harvest delays despite the reduced percentages of starch in the roots. This is indicated in table 12, which shows the yield of starch per acre for the undisturbed-vine plots (calculated from mean root yields and mean starch percentages). Although there are fluctuations in these yields, they do show that the maximum calculated starch yields per acre were sometimes reached as late as 2 weeks after frost.

Vine-Cutting-and-Covering Treatments

Statistical analysis of starch-percentage data showed that vine-cutting-and-covering treatments caused no significant difference in the starch content of Triumph roots in any of the 3 years at either Meridian or Baton Rouge or in the starch content of Porto Rico roots in 1940 and 1942 at Baton Rouge. Variations in starch content with different vine treatments of Porto Rico roots at Baton Rouge were barely significant in 1941.

TABLE 9.—*Starch content (fresh-weight basis) at harvest and after common shed storage for 1 week of Triumph sweetpotato roots harvested at different times*

Location and year	Starch-sampling period	Mean starch content of roots for intended time of harvest indicated							Least significant difference [1]	
		Before frost	At frost	2 weeks after frost	5 weeks after frost	8 weeks after frost	11 weeks after frost	Mean	Between sampling-period means	Between time-of-harvest means
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Meridian:										
1940	At harvest	23. 3	20. 4	--------	[2] 19. 2	[3] 16. 6	13. 7	18. 6	(4)	
	After 1-week storage	23. 1	--------	--------	[2] 19. 2	[3] 14. 9	13. 9	17. 8		--------
	Mean	23. 2	--------	--------	[2] 19. 2	[3] 15. 7	13. 8	--------	--------	1. 2
1941	At harvest	25. 8	24. 6	23. 2	20. 8	15. 9	--------	22. 0	0. 2	
	After 1-week storage	25. 6	24. 0	22. 8	20. 0	15. 9	--------	21. 7		--------
	Mean	25. 7	24. 3	23. 0	20. 4	15. 9	--------	--------	--------	. 5
1942	At harvest	19. 6	17. 8	16. 7	14. 1	11. 8	--------	16. 0	. 2	
	After 1-week storage	18. 8	17. 7	16. 9	13. 6	11. 6	--------	15. 7		--------
	Mean	19. 2	17. 8	16. 8	13. 9	11. 7	--------	--------	--------	. 4
Baton Rouge:										
1940	At harvest	24. 3	23. 7	21. 8	20. 7	--------	--------	22. 6	. 5	
	After 1-week storage	23. 3	22. 6	22. 0	20. 3	--------	--------	22. 1		--------
	Mean	23. 8	23. 1	21. 9	20. 5	--------	--------	--------	--------	. 8
1941	At harvest	22. 1	23. 5	21. 7	--------	--------	--------	22. 4	(4)	
	After 1-week storage	21. 9	24. 2	21. 4	--------	--------	--------	22. 5		--------
	Mean	22. 0	23. 8	21. 5	--------	--------	--------	--------	--------	1. 1
1942	At harvest	24. 8	23. 5	22. 6	19. 0	--------	--------	22. 5	. 5	
	After 1-week storage	24. 4	23. 0	20. 6	17. 9	--------	--------	21. 5		--------
	Mean	24. 6	23. 2	21. 6	18. 4	--------	--------	--------	--------	1. 1

---

[1] At 5-percent level.

[2] 6 weeks after frost.

[3] 9 weeks after frost.

[4] Difference lacks statistical significance.

TABLE 10.—*Starch content (fresh-weight basis) of Porto Rico sweetpotato roots grown at Baton Rouge and harvested at different times*

Time of harvest	Mean starch content of roots at harvest for year indicated		
	1940	1941	1942
	Percent	*Percent*	*Percent*
Before frost	21. 36	19. 35	20. 97
At frost	19. 93	18. 51	19. 49
1 week after frost	----------	18. 15	18. 64
2 weeks after frost	17. 20	17. 49	18. 76
3 weeks after frost	----------	----------	16. 97
4 weeks after frost	----------	16. 33	----------
5 weeks after frost	15. 24	----------	----------
Least significant difference[1] between means for times of harvest	. 57	. 52	. 68

[1] At 5-percent level.

TABLE 11.—*Moisture content of Triumph and Porto Rico sweetpotato roots when harvested at various periods before and after frosts at Meridian and Baton Rouge*

Variety and time of harvest	Moisture content of roots at harvest for location and year indicated[1]					
	Meridian			Baton Rouge		
	1940	1941	1942	1940	1941	1942
Triumph:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Before frost	69. 27	65. 34	72. 25	67. 98	69. 30	66. 48
At frost	69. 82	66. 67	73. 29	67. 78	68. 07	67. 79
2 weeks after frost	-------	67. 92	73. 87	68. 61	69. 53	-------
5 or 6 weeks after frost	70. 20	68. 53	73. 47	69. 55	-------	70. 30
8 or 9 weeks after frost	70. 53	69. 55	76. 02	-------	-------	-------
11 weeks after frost	72. 19	-------	-------	-------	-------	-------
Porto Rico:						
Before frost	69. 04	-------	-------	69. 99	69. 15	70. 01
At frost	68. 88	-------	-------	69. 95	70. 96	69. 76
1 week after frost	-------	-------	-------	-------	71. 17	71. 29
2 weeks after frost	-------	-------	-------	71. 58	71. 37	-------
3 or 4 weeks after frost	-------	-------	-------	-------	73. 10	71. 52
5 or 6 weeks after frost	71. 59	-------	-------	73. 30	-------	-------
9 weeks after frost	74. 77	-------	-------	-------	-------	-------
11 weeks after frost	74. 04	-------	-------	-------	-------	-------

[1] Mean of samples from 2 undisturbed-vine plots.

TABLE 12.—*Calculated yields of starch per acre from undisturbed-vine plots when Triumph and Porto Rico sweetpotatoes were harvested at various times in 3 years at Baton Rouge and Meridian*

Variety and intended time of harvest	Mean yield of starch per acre for location and year indicated [1]					
	Baton Rouge			Meridian		
	1940	1941	1942	1940	1941	1942
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Triumph:						
Before frost	4, 685	4, 335	4, 750	1, 430	5, 090	4, 778
At frost	5, 996	5, 706	4, 341	1, 462	4, 606	4, 180
2 weeks after frost	4, 305	5, 608	4, 596	--------	5, 372	4, 328
5 weeks after frost	3, 340	--------	3, 169	[2] 1, 276	5, 013	3, 185
8 weeks after frost	--------	--------	--------	[3] 1, 148	3, 519	2, 556
Porto Rico:						
Before frost	3, 739	4, 458	3, 022	--------	--------	--------
At frost	3, 729	4, 622	3, 118	--------	--------	--------
2 weeks after frost	2, 821	4, 767	3, 505	--------	--------	--------
5 weeks after frost	2, 626	[4] 4, 645	[5] 3, 051	--------	--------	--------

[1] Calculated from mean root yields and mean starch percentages.

[2] 6 weeks after frost.

[3] 9 weeks after frost.

[4] 4 weeks after frost.

[5] 3 weeks after frost.

It is concluded therefore that cutting vines at the time of the first killing frost caused very little if any alteration in the starch content of roots left in the ground for as long as 8 weeks thereafter. This was true whether the vines were left in place or raked over the row either with or without additional soil coverings.

SHORT HOLDING PERIODS IN COMMON SHED STORAGE AFTER HARVEST

In addition to the percentages of starch found in Triumph roots at each of several harvest periods, table 9 shows the mean starch percentages in comparable roots held for 1 week after each harvest in common shed storage. For most root samples in most tests the starch percentage showed little reduction after 1 week's unheated shed storage. When the starch-percentage data for all harvests in each test were analyzed, the reductions in mean starch content as a result of holding in the unheated shed storage were found to be statistically significant in four of the six tests. Whereas reductions in starch percentages during 1 week of shed storage were, on the average, very small, on a relative basis they ranged from 1.6 to 4.4 percent of the average starch content of the roots at harvest.

From a practical standpoint these results indicate that holding roots in unheated shed storage for 1 week after harvest will usually cause small but unimportant reductions in starch content of sound roots.

KEEPING QUALITIES OF ROOTS PLACED IN COMMON SHED STORAGE

After each harvest both Triumph and Porto Rico roots from the various field treatments were held for approximately 2 months in common shed storage in order to determine to what extent this type of storage might be practical for limited holding periods.

Analysis of data gathered at the end of storage showed that there was little if any effect of the vine-cutting-and-covering treatments on the subsequent keeping quality of the roots in common storage. In an earlier report embracing a part of the studies conducted at Baton Rouge, Kimbrough (*4*) pointed out that after common storage there was no difference in the eating quality of Porto Rico roots obtained from plants from which the vines had been cut the day of frost and those from which they had not been cut. There was no evidence that any injurious material moved from frost-injured uncut vines to roots of the sweetpotato, such as Price (*7*) implied from studies made a number of years ago. However, regardless of whether or not the vines were cut, late-dug Porto Rico roots usually had higher moisture contents and poorer eating quality than early-dug lots. Cooking tests were not made on the roots removed from storage at Meridian or Gilmer.

The percentages of the roots that were sound at the end of the 2-month periods in common shed storage are shown in table 13, together with partial temperature data pertaining to these periods. At Meridian the proportions of unsound Triumph roots at the end of 2 months' storage were considerable for most harvests, even for those made before or at frost. As the harvests were delayed and the storage periods were correspondingly later, the proportions of sound roots found at the end of storage rapidly decreased. Likewise somewhat less rapid but significant losses of roots in storage with delays in harvest occurred with the Porto Rico variety. In general, similar though somewhat less severe losses are indicated in the Baton Rouge 1940 and 1942 and Gilmer 1941 and 1942 data. Wet soils after frosts, progressive declines in soil temperatures before harvest, and progressively lower temperatures in the unheated storage houses as the season advanced all contributed to the greater losses of roots in storage from the more delayed harvests.

Although both the soil-temperature data presented in table 2 and the air-temperature data included in table 13 are incomplete, they suggest that the more drastic losses during common storage at Meridian probably were caused by generally lower minimum and mean soil temperatures before harvest and lower storage temperatures than occurred at Baton Rouge and Gilmer. It was shown by Kimbrough and Bell (*5*) and by Lutz (*6*) that sweetpotatoes are injured by exposure for as little as 2 to 7 days at temperatures above the freezing point but below 40° F. At Baton Rouge in 1941 delaying harvest 2 weeks and even 4 weeks apparently did not cause any greater declines in the proportions of sound roots during storage than were observed for roots harvested at frost.

TABLE 13.—*Sound roots of Triumph and Porto Rico sweetpotatoes harvested at different times from undisturbed-vine plots and stored for 2 months in common shed storage at various temperatures*

Location and year	Time of harvest	Roots sound [1]		Temperatures during storage					
				In storage room			Outside		
		Triumph	Porto Rico	Maximum	Minimum	Mean	Maximum	Minimum	Mean
Meridian:		*Percent*	*Percent*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*
1940	Before frost	54.7	51.6	82	30	59.9	87	17	56.6
	At frost	33.8	47.1	82	30	59.9	87	17	56.6
	6 weeks after frost	25.5	32.5	71	30	52.3	76	25	50.2
	9 weeks after frost	2.9	9.6	69	30	50.1	74	22	48.1
	11 weeks after frost	.6	.0	69	30	48.2	74	22	46.0
1941	Before frost	84.4	84.0	82	41	57.8	91	26	53.9
	At frost	89.6	83.4	73	22	53.2	80	8	48.5
	2 weeks after frost	65.0	62.0	68	22	49.3	74	8	46.2
	5 weeks after frost	.0	6.3	66	22	46.1	72	8	45.5
	8 weeks after frost	.0	.0	60	22	42.4	73	8	44.0
1942	Before frost	52.8	20.4	77	33	53.9	81	26	53.8
	At frost	16.5	69.7	77	33	49.5	80	26	50.7
	2 weeks after frost	1.8	15.4	78	30	47.2	81	14	49.3
	5 weeks after frost	.0	4.6	78	30	49.1	81	14	50.2
	8 weeks after frost	.0	.0	78	28	49.5	81	14	49.2
Baton Rouge:									
1940	Before frost	78.1	88.9						
	At frost	71.3	83.7						
	2 weeks after frost	79.4	74.5						
	5 weeks after frost	16.1	57.1						
1941	Before frost	94.0	84.0				75	52	63.0
	At frost	96.3	85.1				79	31	50.0
	1 week after frost		86.2				82	31	57.5
	2 weeks after frost	96.0	87.0				79	31	59.5
	4 weeks after frost		84.8				75	28	54.0

1942	Before frost	83. 9	81. 5	--------	--------	--------	74	48	61. 5
	At frost	96. 8	86. 7	--------	--------	--------	86	34	60. 0
	1 week after frost	--------	87. 2	--------	--------	--------	80	31	55. 0
	2 weeks after frost	93. 0	74. 9	--------	--------	--------	80	21	51. 0
	3 weeks after frost	--------	73. 7	--------	--------	--------	--------	--------	--------
	5 weeks after frost	59. 8	--------	--------	--------	--------	80	21	52. 0
Gilmer:									
1941	Before frost	--------	91. 0	--------	--------	--------	--------	--------	--------
	At frost	--------	91. 8	--------	--------	--------	--------	--------	--------
	1 week after frost	--------	87. 2	--------	--------	--------	--------	--------	--------
	9 weeks after frost	--------	. 0	--------	--------	--------	--------	--------	--------
1942	Before frost	--------	84. 2	66	53	63. 1	--------	--------	--------
	At frost	--------	87. 9	66	53	63. 0	--------	--------	--------
	1 week after frost	--------	85. 5	65	53	62. 5	--------	--------	--------
	4 weeks after frost	--------	82. 1	64	51	61. 0	--------	--------	--------
	8 weeks after frost	--------	60. 2	65	51	61. 7	--------	--------	--------

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[1] Based on weights at end of 2-month storage.

From these studies it appears that common shed storage of industrial-type sweetpotatoes for periods as long as 2 months will usually prove practical only for roots harvested not later than 2 weeks after the first killing frost, unless the weather is very mild and storage temperatures remain well above 50° F. Although table-type sweetpotatoes may be no more subject to physical break-down in common shed storage after delayed harvest than are roots of industrial types, such storage should be utilized only under emergency conditions. Eating quality of sweetpotatoes is rapidly impaired under such conditions.

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